



**Engineering Science Series**

**ROUTE SURVEYS  
AND CONSTRUCTION**

# ENGINEERING SURVEYS SERIES

---

*A completely coordinated set*

ENGINEERING SURVEYS: ELEMENTARY

*by Rabe, Loomis, and Todd*

ENGINEERING SURVEYS: ELEMENTARY AND  
APPLIED

*by Rabe, Loomis, and Todd*

ROUTE SURVEYS AND CONSTRUCTION

*by Rabe*

PRACTICAL PHOTOGRAMMETRY

*by Sharp*

# ROUTE SURVEYS AND CONSTRUCTION

A Pocket and Reference Book with Tables  
for the Survey, Design, and Construction  
of Highways, Railways, Airways, Tramways,  
Beltways, Canals, Flumes, Levees, Pipe Lines,  
Transmission Lines, and Other Route  
Constructions  
for

Students, Professional Engineers,  
Construction Engineers, and Contractors

HARRY R. RUBBY B.S., C.E., P.E.

MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS  
MEMBER NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS  
MEMBER AMERICAN SOCIETY FOR ENGINEERING EDUCATION  
CHAIRMAN DEPARTMENT OF CIVIL ENGINEERING  
UNIVERSITY OF MISSOURI

THIRD EDITION, BY RUBBY, S.

THE MACMILLAN COMPANY, NEW YORK

## **PREFACE**

This third edition is based on 50 years of the practice and teaching of routes. It has been revised through three editions and numerous printings to serve as a text and permanent reference book emphasizing professional civil engineering and its trend towards the profitable fields of engineered construction, contracting, professional management, and the expanding practical uses of photogrammetry. Fundamentals and disciplines are retained but the traditional field surveying flavor is diminished.

It has been kept in mind that the course in route surveys must provide the engineering approach and the broad basic treatment underlying highways, railways, airways, canals, pipe lines, transmission lines, cableways, beltways and all transportation and communication constructions. Obviously it cannot provide complete coverage of such a wide variety of fields in any of which the graduate may practice. Furthermore, corporations or governmental branches engaged in these fields have varying standards of practice, accompanied by pride of opinion. Since the work of the graduate varies so widely, it would be misleading and narrowing to concentrate on any one field or any single standard practice, as was once done for railways and as is now being done for highways. While highway, railway, and hydraulic constructions are emphasized in this text, other applications are indicated. It is the author's conviction that the engineer should be educated broadly and professionally, not trained narrowly in the techniques of a special field.

Few engineering curricula allow adequate courses and time for engineered construction with its relation to professional management and for modern photogrammetric applications; hence their inclusion in this edition. It is suggested that the economic studies, estimates, and bids of chapters XV and XVII may be made as part of a project investigation in the routes.

construction, or professional management courses. Perhaps in this indirect manner a little additional time may become available for consideration of routes.

Regardless of whether the study of routes be limited to an unduly brief geometric treatment in the sophomore year, a more elaborate study in the junior year, or preferably a professional design and economic project study in the senior year; all civil engineering students, constructors, practitioners, and managers need complete reference material and tables for routes close at hand throughout their careers. The book has been prepared for this overall permanent use as well as for class use in all types of routes courses. Selected chapters may be assigned and covered to any extent desired but the treatment is comprehensive. Any shorter text or any specialized treatment such as is given in railway, highway, and similar manuals necessarily must be on a sub-professional or technician basis unsuited to professional collegiate curricula or for broad professional reference.

Better, broader, and more comprehensive coverage is provided in this book than in other texts for such matters as:

1. More tables, with latest revisions and corrections.
2. Tables and text suitable for arc, chord, and other definitions of degree of curve, including latest methods and tables for staking curves with a tape on secondary roads, logging roads, canals, and the like.
3. Tables and text suitable for the American Railway Engineering Association (railway), the Barnett (highway), and other spirals, treated fundamentally.
4. The latest developments for both string lining (from A.R.E.A. Manual and newest mechanical equipment) and transit lining, on existing railway curves.
5. Several methods of staking railway turnouts.
6. Highway and photogrammetric applications.
7. New chapters and emphasis on the growing and remunerative fields of engineered construction, professional management, and contracting, including estimating and bidding
8. The long-established Macmillan five-place natural trigonometric and log tables that are most efficient for general use. For

rare usage, eight-place natural sines and cosines have been added. No such precise tables are available to most engineers.

9. Facilitating reference by continuing to number all figures, tables, and formulas to correspond to the section in which they occur and giving the chapter and section numbers at the top of each page.

10. Perfecting and expanding the index to increase the reference value of the book and tables.

11. Including extensive problems with answers to the (a) problem in each case so that the student can check them while studying. Similar (b), (c), and (d) problems with varying numerical data are added for examining or quizzing the student.

12. Retaining the type which is more easily read than is that of most pocket books.

13. Avoiding verbose description or formulation which makes a text difficult to follow and removes the student's incentive to reason from a figure and to exercise his own initiative and judgment. On the contrary, figures are ample but simple and the student must give his own thoughtful study to the figures, formulas, and text. Reasoning on the part of the student thus becomes necessary in solving the problems, in explaining simple missing steps in the development of formulas, and in his economic design of location on maps and profiles or on the ground. Open or closed book examinations may then use both problems and objective questions.

14. Perfecting the text and tables through a score of printings and editions.

15. Outlining a project method for teaching a route survey course, as given in Section 12a.

16. Furnishing teaching aids, on request from teachers, especially designed for this book and for the larger classes.

17. Encouraging a professional, rather than a sub-professional, approach.

The more notable changes in this edition place emphasis on professional engineering, engineered-construction, professional management, contracting, and practical photogrammetry; these being the more promising and profitable outlets for the majority

of civil engineers. Here their future is unlimited, whichever way their interests and opportunities develop.

The cooperation of associates in teaching and practice, of students, of manufacturers, of transportation agencies, and of governmental agencies is gratefully acknowledged. The author will be most appreciative of further suggestions for improvement that may be brought to his attention.

HARRY RUBLY

*Columbia, Mo.*



# CONTENTS

NOTE: See also Index and list at beginning of Tables.

## CHAPTER I

SECTION	INTRODUCTION	PAGE
1.	Importance of Route Surveys and Construction . . . . .	1
2.	Selection of Routes . . . . .	2
3.	General Types of Route Surveys . . . . .	4

## CHAPTER II

### THE RECONNAISSANCE

4.	General Considerations . . . . .	5
5.	Topography. . . . .	6
6.	Controlling Points . . . . .	8
7.	Gradients . . . . .	8
8.	Compensated Grades . . . . .	9
9.	Curvature . . . . .	10
10.	Reconnaissance Instruments . . . . .	11
11.	Obtaining Elevations with the Aneroid Barometer . . . . .	11
12.	Aerial Surveys . . . . .	20
12a.	A Project Method for Teaching Route Surveys . . . . .	23
13.	Reconnaissance Procedure . . . . .	23
14.	The Reconnaissance Report. . . . .	24

## CHAPTER III

### THE PRELIMINARY

15.	Purpose of Preliminary . . . . .	26
16.	The Standard Type of Preliminary. . . . .	26
17.	Long Tape Preliminaries . . . . .	34
18.	Stadia Preliminary . . . . .	38
19.	Rapid Stadia Preliminary . . . . .	38
19a.	Aerial Preliminaries . . . . .	38
20.	Precision of Preliminaries. . . . .	38
21.	Checking and Coordinating the Preliminary. . . . .	39
22.	Miscellany . . . . .	40

## CHAPTER IV

### LOCATION

23.	General. . . . .	47
24.	Procedure. . . . .	47
25.	Grade Contour. . . . .	49

<b>SECTION</b>	<b>PAGE</b>
26. Balanced Cuts and Fills	50
27. Exploration of Excavation	51
28. Obtaining Permission to Construct	51
29. Monumenting the Location	52
30. Location Maps and Profiles	52
30a Construction	57

## **CHAPTER V**

### **‘ SIMPLE CIRCULAR CURVES**

31. Introduction	58
32. Degree of Curve	58
33. Functions of Simple Curves	60
34. Curve Notes	63
35. Field Work	66
36. Staking Curves with a Tape	7
37. Triangulating a Curve	7
38. Locating a Curve from the Center	7
39. Special Problems	7
40. Some Solutions by Trial	79
41. In Conclusion	80

## **CHAPTER VI**

### **COMPOUND AND REVERSE CURVES**

42. Compound Curves	81
43. Reverse Curves	86

## **CHAPTER VII**

### **SOLUTION BY TRAVERSE**

44. Solution by Traverse	89
45. Traversing around Obstacles	90
46. Conclusion	91

## **CHAPTER VIII**

### **VERTICAL AND OTHER PARABOLIC CURVES**

47. Parabolic Curves	93
48. Vertical Parabola	93
49. Low Point on Vertical Curve	97
50. Adjacent Vertical Curves	98
51. Length of Vertical Curves	99
52. Laying out Parabolas with a Tape	101

## CONTENTS

xi

### CHAPTER IX

SECTION	SPIRALS	PAGE
53.	Introduction .....	103
54.	Basic Equation of the Spiral ..	104
55.	American Railway Engineering Association Ten-Chord Spiral .....	106
56.	Properties of the A. R. E. A. Spiral .....	108
57.	Precise Definition of A. R. E. A. Spiral .....	115
58.	Spiral Field Notes .....	117
59.	Spiral Field Notes when Stationing Is Preferred .....	120
60.	The Osculating Circle .....	120
61.	Intermediate Setups and Compound Curves ..	121
62.	Field Work .....	124
63.	Field Work by Offsets ..	125
64.	Spiral Tables ..	126
65.	Spiraling Existing Curves ..	126
66.	Superelevation ..	128
67.	Length of Spirals ..	135
67a.	Barnett Transition Curves for Highways ..	138

### CHAPTER X

#### RAILWAY TURNOUTS AND TRACK LAYOUTS

68.	General ..	139
69.	Definitions ..	139
70.	Staking a Turnout from Straight Track ..	141
71.	Turnouts on Curves ..	143
72.	Tracks Curved after Leaving Turnout ..	144
73.	Turnouts from Straight Track ..	145
74.	Connecting Tracks ..	146
75.	"Y" Track Layouts ..	146
76.	Crossovers ..	146
77.	Crossings ..	146
78.	Other Track Layouts ..	147

### CHAPTER XI

#### STRING LINING OF CURVES

79.	General ..	148
80.	String Lining of Railway Curves by Chord Method ..	148
81.	Tools Required ..	150
82.	Procedure ..	150
82a.	Improved Mechanized String Lining ..	156
83.	String Lining as Applied to Park Roads ..	160

## CHAPTER XII

SECTION	EXCAVATION AND EMBANKMENT	PAGE
84	Purpose of the Study	161
85	General Procedure	161
86	Cross-Section Forms	166
87	Setting Slope Stakes	167
88	Precision in Measurements	169
89	Computing End Areas	169
90	Coordinate Method of Computing End Areas	171
91	The Grade Triangle Method	173
92	End Areas by Planimeter	174
93	Sections in Earth and Rock	174
94	Canal Cross Sections	177
95	Averaging End Areas	177
96	Prismoidal Formula	178
97	Prismoidal Correction	179
98	Excavation Tables and Diagrams	181
99	Embankment Openings	183
100	Curvature Correction	184
101	Borrow Pits	187
102	Computation of Grading Over an Area or Borrow Pit Method	188
103	Shrinkage and Swell	192
104	Settlement	193
105	Classification of Excavation	193
106	Grading Equipment and Method	194

## CHAPTER XIII

## HAUL AND THE MASS DIAGRAM

107	Haul	195
108	Free Haul	195
109	Overhaul	195
110	Station to Station Method	197
111	Economic Limit of Haul	199
112	Mass Diagram	200
113	Properties of the Mass Diagram	202
114	Purpose of the Mass Diagram	203
115	Procedure in Using the Mass Diagram	203

## CHAPTER XIV

## RIGHTS OF WAY

116	Influence of Rights of Way on the Selection of Routes	207
117	The Right of Eminent Domain	207

# CONTENTS

xiii

## SECTION

PAGE

118	Right of Way Agents	208
119	Deeds and Easements	208
120	Right of Way Description	208
121	Surveys of Right of Way	209
122	Legal Rights of Surveyors	210

## CHAPTER XV

### CONSTRUCTION

#### CONSTRUCTION PROCEDURE

123	General	212
124	Re-establishing a Final Location and Ordering Materials	212
125	Cross Sectioning	212
126	Staking Appurtenant Structure	212
127	Check Survey	218
128	Inspection	218
129	Contracts	218
130	Monthly Estimate	219
131	Progress Report	219
132	Final Estimate	219
133	Summary	220
134	Operation after Construction	220
135	Management and Administration	221

#### CONSTRUCTION DATA

136	Allowable Bearing Power of Soil	221
137	Bearing Power of Piles	222
138	Strength of Building Material	228
139	Concrete Data	227
140	Waterway Size for Culverts or Bridges	229
141	Flow of Water in Pipes and Open Channels	232
142	Flow of Water over Weirs	232
143	Conversion Factors	239
144	Weights of Materials	240
145	Cost of Various Constructions	240
146	Estimating by Cost per Complete Unit	240
147	Estimates Made from Quantity Surveys	243

## CHAPTER XVI

### THE CONSTRUCTION ENGINEER AND PROFESSIONAL MANAGEMEN

148	Introduction	248
149	The Construction Engineer	248

SECTION	PAGE
150 Organization of the Construction Management Department	250
151. Professional Management .....	251
152 The Rise and Fall of Engineers as Managers	252

## CHAPTER XVII

## THE ENGINEER-CONTRACTOR

153 Introduction	255
154 The Contractor's Equipment	255
155 The Contractor's Organization	256
156 The Contractor's Bid	256
157 Contracting as a Career	261
158 The Contractor's Work	264

## CHAPTER XVIII

COMPARISON OF VARIOUS DEFINITIONS OF DEGREE  
OF CURVE

159 General	265
160 Even-Radius Curves	265
161. Radius of 5730 Feet	266
162 Metric Curves	267
163 Discrepancies	267
164 Comparison of Values under Various Definitions	268

## CHAPTER XIX

## HIGHWAY PRACTICE

165 Purpose of this Chapter	271
166 Geometric Practice	271
167 Location and Design	280
168 An Overall Transportation Policy	285
168a Present Highway Standards	285

## CHAPTER XX

## AERIAL PHOTOGRAPHY IN ROUTE SURVEYING

169 General Considerations	295
170. Example Number I	298
171. Example Number II	300
172. Addendum.	303

## CHAPTER XXI

## PROBLEMS

Chapts. I-XVIII.	304
Tables .. .. .	. following page 315

# **ROUTE SURVEYS AND CONSTRUCTION**





## CHAPTER I

### INTRODUCTION

**I. Importance of Route Surveys and Construction.** Construction, with its accompanying replacement and maintenance, has become our largest industry, accounting for one seventh of our expenditures. It is a most profitable field for civil engineers and offers preferred entree into management. Much of this rapidly growing activity is based on the fundamental data contained herein.

This book presents the principles underlying the design of location, survey, and construction of highways; railways; airways; gas, oil, and water pipe lines; canals and water conveying conduits and flumes; electrical transmission lines; telephone and telegraph lines; tunnels and underground conduits; cableways; beltways; and other means of conveying or transmitting goods, materials, power, or power impulses over long distances on the surface of the earth.

The foregoing routes comprise America's multimillion-mile system of transportation and communication where perhaps one-fifth of our national wealth is invested. The cost per mile for constructing routes varies from a few thousands to many millions of dollars, and operating equipment is equally costly.

Present civilization, its future development, and the high standard of living of this country are dependent to a considerable extent upon its elaborate transportation and communication system. Kipling has said "Transportation is civilization."

In the past, most route construction projects were designed to meet only existing needs, with the result that a large part of this construction is now obsolete. Railways